Principal Components and Wavelet Transforms for Data Compression

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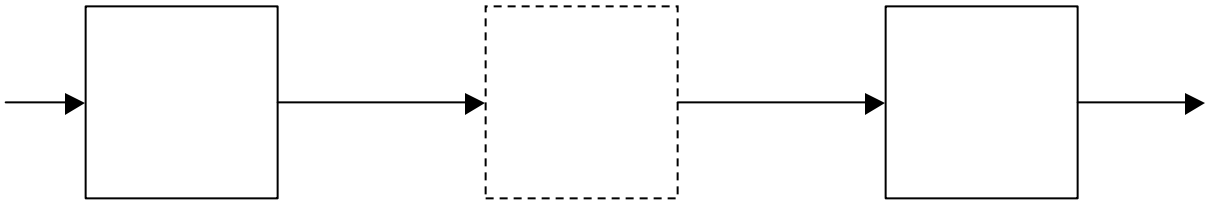
Agenda

- Over view of data compression techniques
- Comparison of KLT/DCT and Wavelet/Subband
- Simulation results
- Future work
- Conclusion

Redundancy Reduction by Compression

Compression is to reduce the redundancy and convey the information with fewer bits by coding



Decorrelating	**Quantization**	**Encoding**
lossless	*lossy*	*lossless*
Identify information	*Remove mixture*	*Binary representation*
(no compression)	*(compression)*	*(compression)*

- **In current technology we can not completely separate true information from redundancy**
- **In lossy compression quantization causes loss of information and degradation of image quality**

Popular Compression Techniques

- **Block Transforms:**
  - **KLT (Karhunen Loeve Transform, Principal Components, Hotelling Transform)**
  - **DCT (Discrete Cosine Transform)**

- **Subband Filters:**
  - **Wavelet Transforms**
  - **M-Band Filter Banks**
  - **MLT (Modulated Lapped Transform)**

KLT of A Two-Variable System

Suppose 2 adjacent pixels are statistically identical because they are highly correlated, then we only need to transmit the average of these two pixels, i. e.,

$y_1 = (x_1 + x_2) / 2$ **major principal component**

$y_2 = (x_1 - x_2) / 2 \sim 0$ **minor principal component**

Common Starting Point

The following 2x2 KLT (a 45 degree rotation)

$$y_1 = (x_1 + x_2) / 2$$

$$y_2 = (x_1 - x_2) / 2$$

is the same as

- **2nd order DCT**
- **2nd order DFT**
- **2nd order Hadamard Transform**
- **2nd order Hartley Transform**
- **Haar Wavelet Transform**

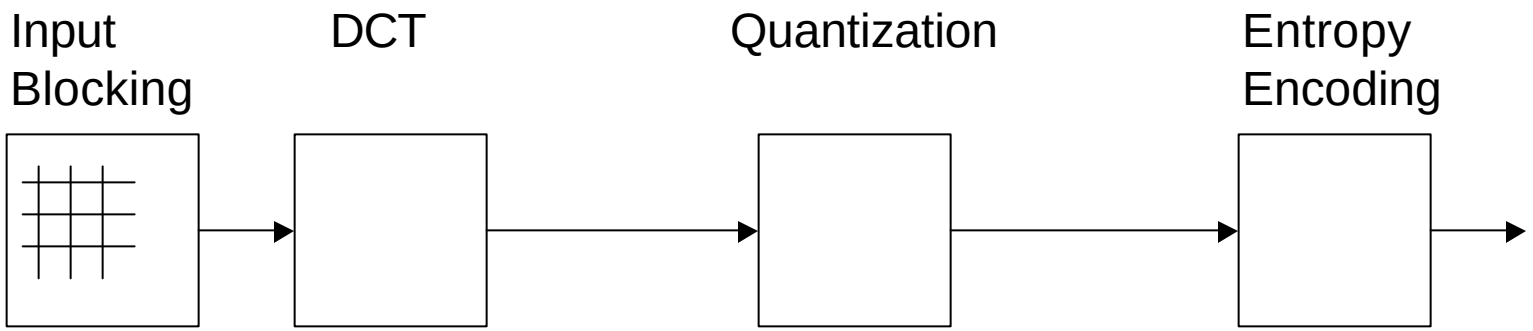
Intrinsic Characteristics of KLT

- **Uncorrelate component pairs within a block of input.**
- **If input are Gaussian, KLT gives the least distortion for a given bitrate among the known block transforms.**
- **Principal vectors need to be transmitted as overhead.**
- **Complex calculations are required in performing a KLT.**
- **For highly correlated components (in uniform area) KLT is indistinguishable from DCT.**
- **In the limiting case of large bitrate and large block size, KLT is equivalent to Fourier Transform for complex input.**
- **Optimal in distortion does not imply optimal in discrimination.**

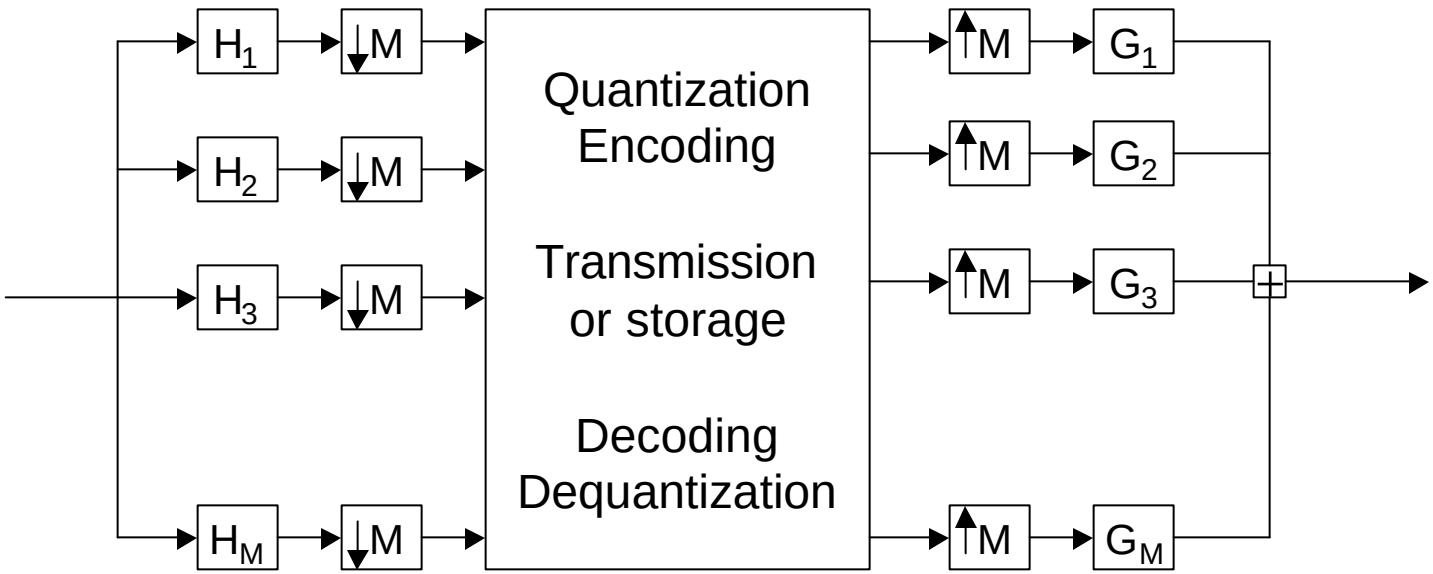
International Standards

- **DCT - used in current International Standards JPEG (Joint Photographic Experts Group) and MPEG (Motion Picture Experts Group).**
- **MLT - used in current International Standard AC-3 (within MPEG-2) for high-quality digital audio compression.**
- **Biorthogonal Wavelet Transform – proposed to be used in future International Standard JPEG 2000.**

JPEG Compression Method



Maximally-Decimated Subband Filters



Analysis Filter Bank

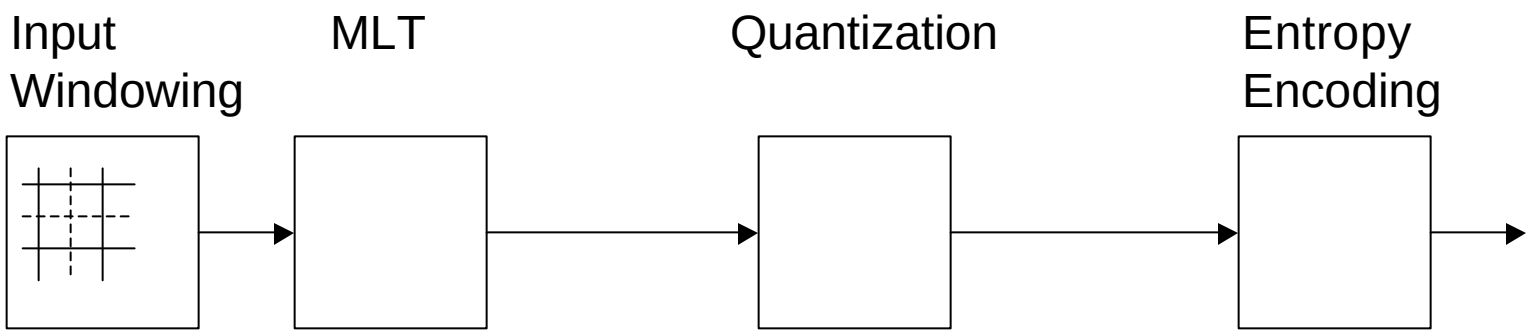
Down Sampling

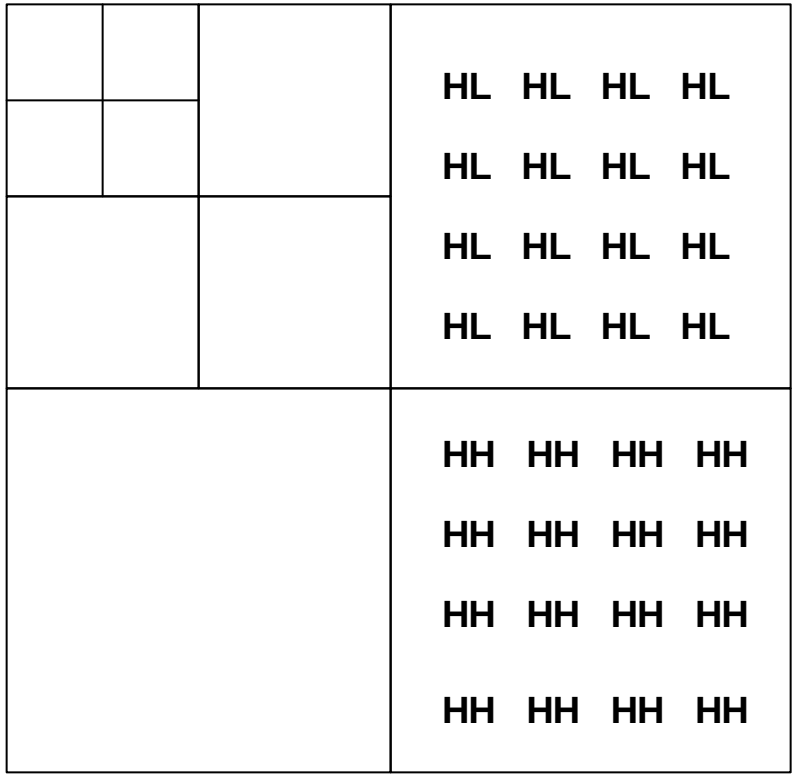
Processing

Up Sampling

Synthesis Filter Bank

MLT Compression Method




HL HL HL HL
HL HL HL HL
HL HL HL HL
HL HL HL HL
HH HH HH HH
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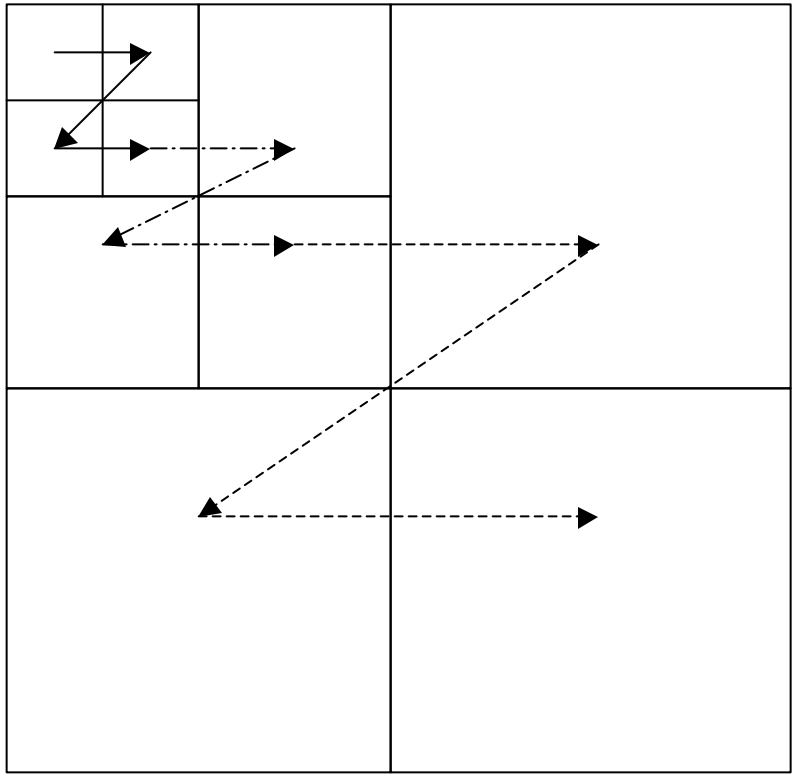


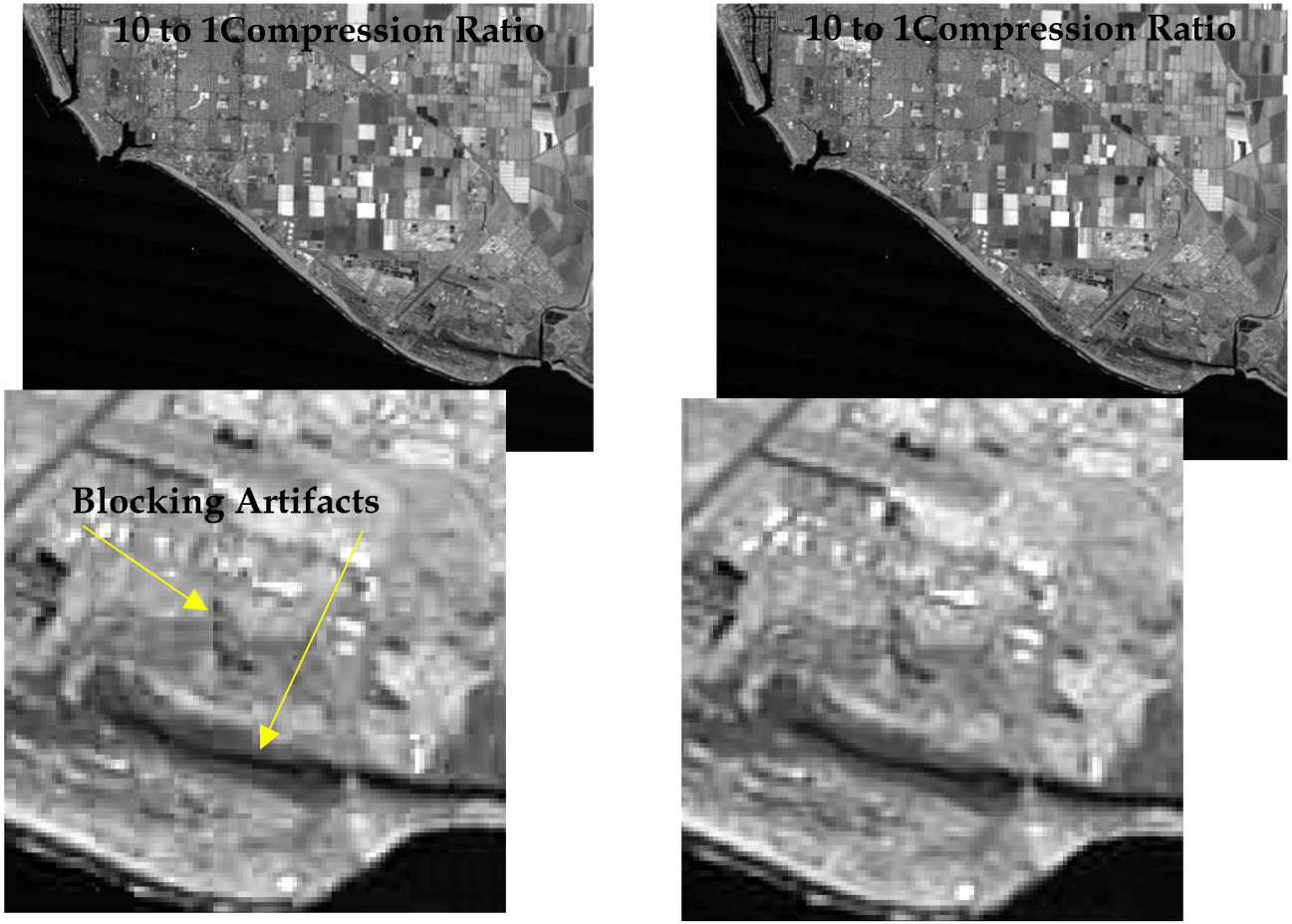
Characteristics of MLT

- **Multiple resolution bands**
- **Parallel frequency channels**
- **Overlapped windowed DCT**
- **Alias of MLT:**
  - **MDCT (Modified DCT)**
  - **Cosine Modulated Filter Banks**
  - **Cosine Modulated Wavelet Transform**
  - **Local Cosine-Basis Wavelet Transform**
  - **Extended Lapped Transform**
  - **M-band Subband Filters**

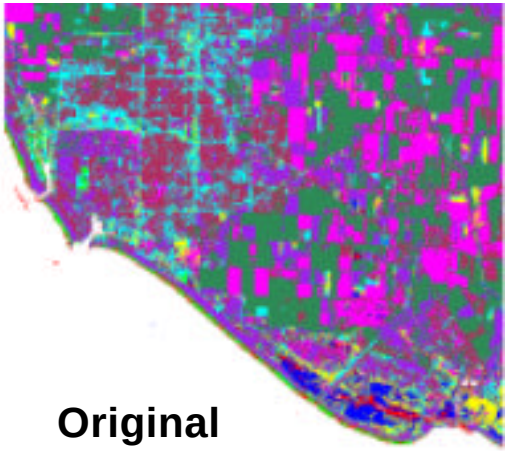
Blocking Effects Example

(Compression ratio is 10 to 1)

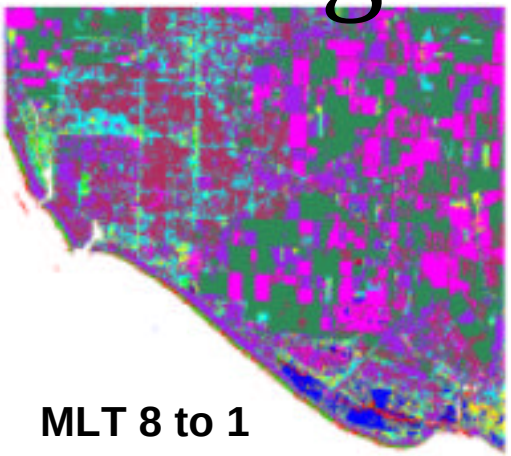
JPEG **MLT**



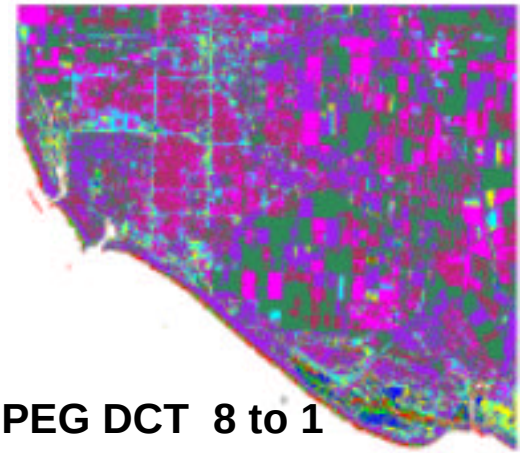
Terrain Categorization



Original



MLT 8 to 1
89 % Correct



JPEG DCT 8 to 1
81 % Correct

Future Work

- **Data compression of hyperspectral data**
- **Feature extraction in Wavelet Transformed domain**
- **Integration of lossless and lossy data compression**
- **Error resistance transmission of compressed data**

Advantages of MLT/Wavelet Transform Data Compression Techniques

- Generally superior data/image quality
- Separates high-resolution parts of image from low-resolution regions
- Better control of data rate
- Can suppress sensor noise
- Potential exists for integrating lossless and lossy data compression techniques into one architecture
- Offers fast computation algorithm for KLT
- Compatible to future international standards
- State-of-the-art techniques for feature extraction